1986 DA AND 1986 EB: M-CLASS ASTEROIDS IN NEAR-EARTH ORBITS

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The earth-approaching asteroid population is composed of asteroids in orbits with lifetimes short compared with the age of the solar system. These objects which are comprised of Aten, Apollo, and Amor asteroids must be replenished from either cometary or mainbelt asteroid sources since lifetimes against collision with or ejection by a planet are on the order of 10 to 100 million years. Without a source, the number of such objects, postulated to be as large as 1,500 (Shoemaker, 1979), would be quickly depleted. Suggestions for sources has ranged from cometary (Opik, 1951) to a combination of asteroidal and cometary (c.f. Shoemaker, 1979; Wetherill, 1986). A cometary source implies that the compositions consistent with the non-volatile remnants of a comet (Hartmann, et al., 1986) where as an asteroidal source would imply that the compositions consistent with the asteroidal source region.

The physical study of Earth-approaching asteroids is constrained by the generally long period between favorable apparitions and poorly known orbits. For example, although 88 such asteroids have been discovered through 1985 only 47 had orbital elements sufficiently reliable to receive permanent numbers (Hahn, 1986). For this reason, these objects must be studied as "targets of opportunity" as soon as they are discovered and before orbital elements are firmly established and a permanent number is assigned. Such is the case for objects 1986 DA and 1986 EB.

1986 DA and 1986 EB were discovered on 16 February 1986 by M. Kizawa, Shozouka, Japan and on 4 March 1986 by E. Shoemaker and C. Shoemaker, Palomar Observatory, respectively (IAU Circ. 4181 and 4191). 1986 DA is a member of the Amor group since its orbital elements cause it to cross the orbit of Mars but not the Earth whereas 1986 EB is a member of the Aten group since its orbital elements cause it to cross the orbit of the Earth even though its semimajor axis is less than 1 AU.

Broadband spectrophotometry on the Johnson UBVR system and the Eight-Color Asteroid Survey system (Tedesco, et al., 1982) were obtained at Kitt Peak National Observatory and on the Johnson JHK system and at 10 and 20 microns at the NASA Infrared Telescopy Facility at Mauna Kea Observatory (Tedesco and Gradie, 1987). These observations were used to determine the absolute visual magnitudes and to derive the visual geometric albedos and diameters on the IRAS system (Lebofsky, et al., 1987) given in Table I.

Table I. UBV colors and mean albedos and diameters.

Object	H	G	U-B	B-V	pv	Diameter (km)
1986 DA	15.94	0.25	0.21	0.70	0.14	2.3
1986 EB	15.94	0.25	0.24	0.71	0.19	2.0

The UBV colors and the albedos are enough to uniquely classify these two objects on the taxonomic system of Gradie and Tedesco (1982) as class M, the first of these objects to be found in the planet crossing population.

The spectral reflectance properties and geometeric albedos of the M-class asteroids are consistent with compositions analogous to the iron-nickel meteorites or the enstatite-metal assemblages of the enstatite chondrites (Zellner, 1979). Radar observations by Ostro, et al. (1985) of the M-class asteroid 16 Psyche indicate a body nearly entirely of metal. These results imply that both 1986 DA and 1986 EB are probably nearly entirely metallic in composition, perhaps similar in gross composition to the iron meteorites.

The identification of two objects probably of entirely metallic composition has important implications for 1) the origin of the objects currently found in near-earth orbit, 2) the timescales for the delivery of iron meteorites to the earth and 3) the sources of raw materials for space industrialization.

Tedesco and Gradie (1987) examine the issue of the source(s) of the near-Earth asteroids population by comparing the classifications on the scheme employed by Gradie and Tedesco (1982) of 38 such asteroids. Those asteroids for which an unambiguous C, S, or M classification could not be assigned were called "Others" (e.g. D, E, F, P, R or unclassifiable). Five objects were classified as C, twenty-four as S, two as M (1986 DA and 1986 EB), and seven as "Other". The predominance of the well-known C, S, and M classes of asteroids (>80%) in this population strongly suggests that the source region is the asteroid belt unless cometary nuclei are compositionally indistinguishable from the C, S, and M class of asteroids. Furthermore, the presence of M-class asteroids in the near-Earth population argues that the source in the asteroid belt must be close to the 3:1 and 5:2 Kirkwood gaps since these are the only regions in the belt where M-class asteroids are found.

If the source of most of the near-Earth objects is indeed the asteroid belt as our observations suggest, then a method for removing extinct nuclei of short period comets must be found since the rate of production of short period comets from the long period comets is relatively large. We suggest that the lack of a large number of objects with compositions consistent with that expected for short period comets, i.e., dark and spectrally reddened (Hartmann, et al., 1986), argues that either the majority of comets lack cohesive, volatile-free cores and end up as meteor streams or the core of a comet may be so friable that it cannot survive intact as long as asteroidal material.

The two metallic objects , 1986 DA and 1986 EB, provide examples of near-Earth, intermediate parent bodies of some iron meteorites. Using the meteorite production model of Greenberg and Chapman (1983) we calculate that half of the iron meteorites should come from these two objects. These irons should have cosmic-ray exposure ages of < 100 million years, the mean lifetime of most objects in planet-crossing orbits. However, the cosmic-ray

exposure ages of nearly all iron meteorites measure to date are 4 to 20 times older which implies that these irons came directly from the asteroid belt as meter-sized objects without the need for an intermediate parent body. This discrepancy suggests that either that meteorite production from near-Earth iron objects is extremely inefficient or, as Wasson (1985) points out, the small number of irons with cosmic-ray exposure ages less than 200 million years my be the result of experimental bias.

Finally, we note that 1986 DA and 1986 EB, if indeed similar in gross composition to the iron-nickel meteorites, could prove to be valuable sources of raw materials for space industrialization since relative transportation costs to and from these objects could be greatly reduced. Such objects would contain not only iron (90-95 wt%) and nickel (5-10 wt%) but also cobalt (0.6 wt%) and sizeable trace amounts of other elements including gold, platinum group metals.

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